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## **A randomized controlled clinical trial of 3-unit posterior zirconia-ceramic fixed dental prostheses (FDP) with layered or pressed veneering ceramics: 3-year results**

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**Abstract:** **OBJECTIVES:** The aim of the present pilot study was to test whether or not posterior zirconia-ceramic fixed dental prostheses (FDPs) with pressed veneering ceramic exhibit less chipping than FDPs with layered veneering ceramics. **METHODS:** Forty patients (13 female, 27 male; mean age 54 years (range 26.1-80.7 years) in need of one maxillary or mandibular three-unit FDP in the second premolar or molar region were recruited and treated at two separate centers at the University of Zurich according to the same study protocol. The frameworks were made out of zirconia using a CAD/CAM system (Cerec Sirona, Bensheim, Germany). The patients were randomly assigned to either the test group (zirconia frameworks veneered with pressed ceramic; IPS e.max ZirPress, Ivoclar Vivadent AG, Schaan, Liechtenstein; n=20) or the control group (layered veneering ceramic; IPS e.max Ceram, Ivoclar Vivadent AG, Schaan, Liechtenstein; n=20). All FDPs were adhesively cemented and evaluated at baseline (i.e., cementation), at 6 months and at 1 and 3 years of clinical service. The survival of the reconstruction was recorded. The technical outcome was assessed using modified United States Public Health Services (USPHS) criteria. The biologic parameters analyzed at abutment teeth and analogous non-restored teeth included probing pocket depth (PPD), plaque control record (PCR), bleeding on probing (BOP), and tooth vitality (CO<sub>2</sub>). Data was descriptively analyzed and survival was calculated using Kaplan-Meier statistics. **RESULTS:** 36 patients (25 female, 11 male; mean age 52.3 years) with 18 test and 18 control FDPs were examined after a mean follow-up of 36 months (95% CI: 32.6-39.1 months). Comparison of groups was done by Crosstabulation showing even distribution of the respective restored teeth amidst the groups. Survival rate was 100% for both test and control FDPs. Chipping of the veneering ceramic tended to occur more frequently in test (n=8; 40%) than in control (n=4; 20%) FDPs, albeit not significantly (p=0.3). No further differences of the technical outcomes of test and control FDPs occurred. In both test and control group healthy conditions and no difference of the biologic parameters at the abutment and un-restored teeth was found. **CONCLUSION:** Zirconia FDPs with pressed and layered veneering ceramics exhibited similar outcomes at 3 years. A trend to more chipping of the pressed veneering ceramic, however, was observed. **CLINICAL SIGNIFICANCE:** Posterior restorations with zirconia frameworks are a viable treatment method. When restoring posterior teeth with all-ceramic restorations, care providers should be aware of the higher rate of chipping compared to the published data on conventional metal-ceramic restorations.

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# **A randomized controlled clinical pilot study of 3-unit posterior zirconia–ceramic fixed dental prostheses (FDPs) with layered or pressed veneering ceramics: 3- year results**

Keywords: ceramics, fixed-dental prostheses, zirconia, pressed ceramic

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# **A randomized controlled clinical pilot study of 3-unit posterior zirconia–ceramic fixed dental prostheses (FDPs) with layered or pressed veneering ceramics: 3- year results**

## **Abstract**

### **Objectives**

The aim of the present pilot study was to test whether or not posterior zirconia-ceramic fixed dental prostheses (FDPs) with pressed veneering ceramic exhibit less chipping than FDPs with layered veneering ceramics.

### **Methods**

Forty patients (13 female, 27 male; mean age 54 years (range 26.1-80.7 years) in need of one maxillary or mandibular three-unit FDP in the second premolar or molar region were recruited and treated at two separate centers at the University of Zurich according to the same study protocol. The frameworks were made out of zirconia using a CAD/CAM system (Cerec Sirona, Bensheim, Germany). The patients were randomly assigned to either the test group (zirconia frameworks veneered with pressed ceramic; IPS e.maxZirPress, Ivoclar Vivadent AG, Schaan, Liechtenstein; n=20) or the control group (layered veneering ceramic; IPS e.max Ceram, Ivoclar Vivadent AG, Schaan, Liechtenstein; n=20).

All FDPs were adhesively cemented and evaluated at baseline (i.e. cementation), at 6 months and at 1 and 3 years of clinical service. The survival of the reconstruction was recorded. The technical outcome was assessed using modified United States Public Health Services (USPHS) criteria. The biologic parameters analyzed at abutment teeth and analogous non-restored teeth included probing pocket depth (PPD),

plaque control record (PCR), bleeding on probing (BOP), and tooth vitality ( $\text{CO}_2$ ).

Data was descriptively analyzed and survival was calculated using Kaplan-Meier statistics.

## **Results**

36 patients (25 female, 11 male; mean age 52.3y) with 18 test and 18 control FDPs were examined after a mean follow-up of 36 months (95% CI: 32.6 – 39.1 months). Comparison of groups was done by Crosstabulation showing even distribution of the respective restored teeth amidst the groups.

Survival rate was 100% for both test and control FDPs. Chipping of the veneering ceramic tended to occur more frequently in test (n=8; 40%) than in control (n=4; 20%) FDPs, albeit not significantly ( $p=0.3$ ). No further differences of the technical outcomes of test and control FDPs occurred.

In both test and control group healthy conditions and no difference of the biologic parameters at the abutment and un-restored teeth was found.

## **Conclusion**

Zirconia FDPs with pressed and layered veneering ceramics exhibited similar outcomes at 3 years. A trend to more chipping of the pressed veneering ceramic, however, was observed.

## **Clinical Significance**

Posterior restorations with zirconia frameworks are a viable treatment method. When restoring posterior teeth with all-ceramic restorations, care providers should be aware of the higher rate of chipping compared to the published data on conventional metal-ceramic restorations.

## Introduction

The demand for metal-free reconstructions is constantly rising and has led to the development of new dental materials such as high-strength ceramic zirconia. Zirconia exhibits the highest mechanical stability of all available dental ceramics and has a tooth-resembling color which makes it advantageous to metal (1). Numerous clinical studies show good medium- to long-term performance of zirconia when used for the fabrication of frameworks (2)(3)(4, 5)(6). However, when compared to metal-ceramic fixed dental prostheses (FDPs), full-ceramic restorations show significantly lower survival rates after 5 years. (7) The main issue of the zirconia-based restorations is their high rate of technical complications, most specifically chipping of the veneering ceramic. (7)

Rates of 54% of chipping of zirconia veneering ceramic were reported, leading to the clinical issue that zirconia-ceramic FDPs are still much more prone to technical complications than metal-ceramic FDPs. (8). Despite that most of the observed chippings were of minor size and only few are reported to require replacement of the zirconia-ceramic FDPs (8), chipping of the zirconia veneering ceramic remains to be a major clinical issue (8) (2).

One recently introduced new and promising method for veneering zirconia frameworks is the process of heat pressing the veneering ceramic onto the zirconia framework. As heat treating significantly reduces the flexural strength of the ceramic, (9) this technique may help reducing the high chipping rates. When applying this technique, the desired shape of the veneering coating is modeled onto the framework using wax.

Thereafter the framework is embedded according to the lost-wax technique. (10) This method offers the clinical advantage of having the possibility for an intraoral try-in of the restoration before finalisation. The anatomical shape of the planned reconstruction can thus be evaluated prior to the pressing (11).

It is assumed that this new technique may be advantageous to conventional veneering procedures for different reasons. The pressing technique may be less time consuming and less technique sensitive compared to the manual layering. Furthermore, pressing of the veneering ceramic may offer better accuracy, homogeneity and, hence, stability of the ceramic. (12) Whilst by manually layering veneering ceramic the inclusion of micro-pores and trapped air cannot be avoided, the processing of the veneering ceramic using the lost-wax technique may minimize flaws and micro-pores. (13) These intrinsic defects may induce the initiation of cracks during clinical loading. As a result, crack-propagation can lead to chipping of the veneering ceramic and even framework-fractures of the all-ceramic FDP. (14)

Until today only limited clinical data is available indicating that pressing the veneering ceramic onto zirconia frameworks may be superior to the conventional layering technique. Two recent systematic reviews indicate promising clinical outcomes of zirconia-ceramic FDPs when using this technique for veneering (8) (2) The chipping rate was significantly lower with pressed as compared to layered veneering ceramic both for FDPs with zirconia and metal ceramic frameworks. (8)

Interestingly, one clinical study of zirconia FDPs with pressed veneering ceramic showed no chipping whatsoever of the pressed zirconia veneering ceramic after a follow-up period of 40 months (15). Yet, this study was not randomized and only a limited number of patients were included.

Therefore, the aim of the present randomized controlled clinical pilot study was to test the clinical outcomes of zirconia-ceramic FDPs veneered with pressed and layered veneering ceramics.

The hypothesis was that FDPs with pressed veneering ceramic exhibit less chipping than the ones with manually layered veneering ceramics .

## **Material and Methods**

### **Study design and patient selection**

This study was designed as a pilot randomized controlled clinical trial (RCT) to account for the lack of scientific information about the tested type of veneering ceramic for zirconia, therefore, no sample size calculation was performed. Two clinics at the Center of Dental Medicine at the University of Zurich (KBTM, PPK/SZCR) took part in this investigation following one study protocol.

Patients in need of a three-unit FDP in the premolar or molar region were recruited. If the patients presented with multiple tooth gaps, the site to be included in this study was randomly selected. The local ethical committee approved of all the procedures and materials (Ref.Nr. StV 02/09). Informed consent was provided by each participant.

Inclusion criteria for patients and abutment teeth were:



- good general health (no systemic disease that should negatively influence the clinical outcomes.)
- periodontally healthy (Plaque Indices and Bleeding on Probing had to be below 20% previously to the prosthodontic treatment.)
- no obvious signs or symptoms of bruxing and/or clenching (bruxism such as attritions and existing fractures on the patients natural teeth or reconstructions, no pain on muscular palpation or tendomyopathies, no pain causing joint sound, no self-reported bruxing or clenching)
- abutment teeth in need of reconstruction (abutment teeth with existing extensive cavities, fillings or crowns)
- abutment teeth either vital or with lege artis endodontic treatment (post and core build-ups included metal posts and composite build-up (in case of sufficient endodontic filling and post build-up these were left unchanged); or glass-fiber post and composite build-up in case of renewal of an existing post or insufficient remaining tooth structure)
- non-vital abutment teeth with positive long-term prognosis upon clinical and radiological assessment (no peri-apical or apparent periodontal lesions)

Exclusion criteria for patients and abutment teeth were:

Patients not willing or able to achieve sufficient oral hygiene (i.e. PI and BoP below 20%)

The patients were randomly assigned to one of the following treatment groups:

**Test group:** 20 patients receiving a zirconia- ceramic fixed dental prosthesis (FDP) with pressed veneering ceramic (IPS e.max ZirPress, Ivoclar Vivadent AG, Schaan, Liechtenstein).

**Control group:** 20 patients receiving an FDP with conventionally layered veneering ceramic (IPS e. max Ceram Margin, IPS e.max Ceram Dentin and Enamel, Ivoclar Vivadent AG, Schaan, Liechtenstein).

All patients were randomly assigned to the treatment modality and the respective clinic by means of a random list with even and uneven numbers. The 40 patients were evenly distributed between the two centers.

### **Clinical procedures**

The patients were treated between September 2009 and January 2010. The abutment teeth were prepared according to the guidelines for all-ceramic FDPs. After completion of the preparation the vital abutment teeth were treated with a dentine adhesive system (Syntac Classic, Ivoclar Vivadent AG, Schaan, Liechtenstein) to seal the dentinal tubules. Impressions were taken with an A-silicone impression material (President, Coltène Whaledent, Altstätten, Switzerland / Honigum, DMG, Hamburg, Germany) performing double-mix technique. The impression of the opposite jaw was taken with alginate. Provisional restorations were fabricated chair-side using a composite material (ProTemp, 3M ESPE, Seefeld, Germany) and cemented with an eugenol- free temporary cement (Freegenol).

### **Framework fabrication**

The FDPs were fabricated by specialized dental technicians who had received training in the new veneering technique prior to the start of the study. The impressions were poured with scan stone (Camtech-Roc, Picodent, Witterfürth, Germany) and the casts were scanned using a CAD/CAM scanner (inEOS Scanner, Sirona, Bensheim, Germany). The frameworks were virtually designed by means of the corresponding software of the CAD/CAM system (Cerec V2.6 R2005 Sirona, Bensheim, Germany). The frameworks were milled out of Y-TZP partially sintered zirconia ceramic blanks (IPS e max ZirCAD, Ivoclar Vivadent AG, Schaan, Liechtenstein) with the chair-side milling unit of the CAD/ CAM system (inLab milling unit, Sirona, Bensheim, Germany). After milling the frameworks were sintered to full density in a high-temperature furnace (Nabertherm LHT02/16, Lilienthal, Germany).

Before veneering, the frameworks were clinically checked with special emphasis to fit, shape and size of the connectors and the anatomical support of the veneering ceramics.

## **Veneering procedures**

### **Test group:**

After sintering, the frameworks were cleaned with water. They were then coated with a liner (IPS e max Ceram ZirLiner, Ivoclar Vivadent AG, Schaan, Liechtenstein) and baked at 960°C to achieve better bond between framework and veneering ceramic. The frameworks in this group were veneered with pressed veneering ceramic (IPS e.max ZirPress, Ivoclar Vivadent AG, Schaan, Liechtenstein). The procedures for over-pressing

were performed according to the lost wax technique following the manufacturer's directions. In brief, a wax-up of the desired anatomical shape of the veneering ceramic was modeled onto each framework. A minimal thickness of the veneering ceramic of 0.7 mm was provided. The frameworks with wax-ups were embedded in investment compound (IPS PressVEST, Ivoclar Vivadent AG, Schaan, Liechtenstein) and then placed in a furnace (EP600, Ivoclar Vivadent, Schaan, Liechtenstein) at 850°C to burn out the wax. The veneering ceramic ingots (IPS e max ZirPress, Ivoclar Vivadent AG, Schaan, Liechtenstein) were heated and pressed onto the frameworks at 900- 910°C according to the manufacturer's directions. The finishing of the veneered FDPs was performed manually using diamond burs, painting colors and a glazing ceramic (IPS e.max Ceram Glaze Paste, Ivoclar Vivadent AG, Schaan, Liechtenstein).

In the test group 10 FDPs were slightly modified out of esthetic reasons by superficially reducing the pressed veneering ceramic at the buccal side by approximately 0.5mm and by layering one coat of veneering ceramic onto the surface.

At all test FDPs the finishing firing step of the glazing ceramic (IPS e max Ceram Glaze Paste and Glaze and Stain Liquid, Ivoclar Vivadent AG, Schaan, Liechtenstein) was performed at 725°C.

### **Control group:**

According to the procedures in the test group the zirconia frameworks were cleaned with water after the sintering process. To achieve better bond between framework and veneering ceramic again the frameworks were

coated with a liner (IPS e max Ceram ZirLiner, Ivoclar Vivadent AG, Schaan, Liechtenstein), and baked at 960°C in a furnace. The respective veneering ceramics (IPS e. max Ceram Margin, IPS e.max Ceram Dentin and Enamel, Ivoclar Vivadent AG, Schaan, Liechtenstein) were then applied in layers onto the frameworks and baked at 750°C respectively 725°C according to the manufacturer's directions. A conventional furnace was used (OralDesign, Austromat M, Dekema, Freilassing, Germany).

The veneering ceramic was finally smoothened and polished with pumice and polishing liquid (KMG Poliermittel, Candulor AG, Wangen, Switzerland).

### **Cementation**

Before cementation the marginal fit, inter-proximal contacts and the occlusion of the final FDPs were clinically checked. The internal surfaces of the FDPs were cleaned with alcohol and the abutment teeth were cleaned with fluoride-free pumice (Cleanic Prophypaste for Cleaning and Polishing, Kerr Hawe SA, Bioggio, Switzerland).

All FDPs were adhesively cemented with resin cement (Panavia 21 TC, Kuraray, Japan). According to the manufacturer's directions of the resin cement a dentin primer (ED Primer, Kuraray, Japan) was applied to the dentin. No pre-treatment of the zirconia surface was performed. After cementation, the occlusion was adjusted if needed and any reshaped surfaces were meticulously polished with ceramic polishers (Komet nos. 9425, 9426, 9547, Brasseler).

### **Baseline and follow-up examinations**

At baseline (up to 2 weeks post- cementation), and again after 6 months, 1 and 3 years of function the FDPs were examined clinically and radiologically. Beforehand a calibration meeting was held where the examining dentists were instructed and trained. In order to avoid bias the FDPs were examined by two clinicians who were not involved in the reconstructive treatment. Survival of the FDPs was assessed and defined as FDP in situ at follow- up visit with or without modification.

Technical outcomes were evaluated by means of modified United States Public Health Services (USPHS) criteria (17). Parameters were analyzed in detail (Table 1) Finally, the patients were asked by the dentist whether or not they were satisfied with the esthetic outcome and the functionality of their FDP and the respective answer (yes/no) was noted. (Table 1)

The biological outcome was evaluated by means of probing pocket depth (PPD), plaque control record (PCR) (16) and Bleeding on probing (BOP). These parameters were measured at test (abutment) and control teeth (un-restored analogous control teeth). The abutment tooth vitality was checked (CO<sub>2</sub>) and radiographs of the abutment teeth were made.

### **Statistical analysis**

Data was analyzed descriptively. Survival and success rates were determined according to the USPHS criteria and calculated using Kaplan-

Meier. Biological data was analyzed using the paired t-test. Data was analyzed by SPSS version 17.0 (SPSS Statistics, IBM, Armonk NY, USA).

## **Results**

After a mean observation period of 36 months (95% CI: 32.6 – 39.1 m), 36 out of the initial 40 patients were examined (11 male, 25 female). The mean age of the patients at the 3-year follow-up visit was 52.3 years (95% CI: 46.9 – 57.6 y) in the test group and 55.8 years (95% CI: 50.6 – 60.9 y) in the control group.

Four patients (2 test and 2 control) were not available for the 3-year examination. They did show up for the 1-year recall and later moved away without giving notice. The FDPs lost to the 3-year examination were replacing one maxillary molar and one mandibular premolar (control) as well as one maxillary premolar and one mandibular molar (test).

The mean follow-up of the FDPs in the test group was 36.8 months (95% CI: 32.5 – 41.1 m). The corresponding follow-up for the control group was 34.9 months (95% CI: 29.6 – 40.2 m). (Tables 2a-e)

### **FDP survival**

No framework fractures occurred and no FDP was lost due to another reason. Hence, both test and control FDPs had a 100% survival rate.

### **Technical outcomes**

Technical evaluation of the FDPs included debonding, surface roughness and chipping of the veneering ceramic. Table 3

No de-bonding of the examined FDPs occurred.



Surface roughness was observed in 18 patients (14 test (70%) and 7 control (35%) group) ( $p=0.056$ ), which showed a tendency toward statistical significance. When evaluated regarding survival and time between event of surface roughness and chipping, values did not show to be statistically significant. ( $p=0.487$ )

Chipping occurred in 33,2% of all FDPs. Of these 13,8% were minor (rated B) and 19,4% were major (rated C). A total of 8 FDPs (40%) of the test group and 4 FDPs (20%) of the control group exhibited chipping of the veneering ceramics. According to the modified USPHS criteria 3 chippings from the test group were minor and 5 were major In the control group the chippings were evenly distributed with 2 minor and 2 major fractures.

Table 4

The difference in major chippings (rated C) was not statistically significant (Breslow  $p= 0.138$ ) between the groups. All of the chippings were clinically polishable.

### **Biological outcomes**

Differences in PPD, PCR and BoP were statistically not significant but for PPD (0.003 one sample t-test). An overview of the biological evaluation is given in Table 5

None of the abutment teeth lost its vitality during the observation period.

### **Patient satisfaction**

The patients in the test group were significantly less satisfied with their FDPs ( $p>0.047$  Fisher's Exact Test).

## Discussion

The 3- year survival rate for both zirconia-ceramic FDPs veneered with layered and pressed veneering ceramic was 100%. No framework fractures and no de-bonding occurred within the observation period. Thus the two tested types of zirconia-ceramic FDPs exhibited fairly good outcomes at 3 years of function.

The test and control FDPs exhibited no differences with respect to the technical outcomes. A trend towards more chipping of the pressed veneering ceramic could be observed, yet the difference did not reach statistical significance. The hypothesis, therefore, was rejected.

As short-span posterior FDPs with frameworks made of zirconia exhibit very satisfying survival rates of 97.8-100% after 3 years, it has been widely accepted that zirconia is a reliable material for frameworks. (6, 8) Literature shows that even after observation times of 5-10 years very few fractures of zirconia frameworks occurred. (5, 6, 18, 19)

As opposed to this, chipping of the veneering ceramic still remains to be a major technical complication of zirconia- ceramic FDPs (8).

Numerous attempts were made to reduce the chipping rate by developing new veneering ceramics with better intrinsic stability, improving the chemical adhesion to the underlying framework, and adaptation of the manufacturing techniques (i.e. pressing, CAD-on).

Instead of manually layering the veneering ceramic, in this study the ceramic was applied by pressing it onto the zirconia framework. It was

assumed that this technique would induce less risk for chipping due to higher homogeneity of the ceramic. (12, 21, 22)

The first published study on pressed veneering ceramic by Beuer and co-workers showed no chipping of 3-unit zirconia FDPs after an observation period of 3-years when veneered with this technique. (23) Heintze and coworkers stated that chipping of the veneering ceramic occurred less frequently in pressed than in layered ceramics (8). These positive findings were not observed in the present study. ~~This was in vast contrast to our expectations.~~ Chippings within the test group occurred to a similar or even slightly higher amount than in the group with the layered veneering ceramic. A possible reason for this difference may be that in the present study a new material was used and that the technique itself was at an early stage. In the future the veneering procedures would probably need some refinements.

In-vitro studies showed that the main reason for chipping was a cohesive fracture of the veneering ceramic, meaning fractures happening within the veneering ceramic. (1) (11) The fact that the chippings occur within the veneering ceramic and not at the framework interface allows most chippings to be polished rather than having to replace the whole reconstruction. This was the case in the present study as well, as all chippings could be polished and none of the FDPs had to be replaced.

Besides the observation for chipping, the FDPs showed excellent technical and biologic integration.

No statistically significant differences of the biologic outcomes were found at test and control FDPs but for Plaque Indices (PI). These were higher at the control than at the test teeth ( $p=.003$ ). This may be explained by the fact that ceramics are reported to be less prone to plaque accumulation. Another reason might be that the patients were aware of their reconstruction and hence performed better mechanical plaque-removal at the sites with the reconstruction.

The patient satisfaction in the pressed group was lower due to a higher incidence of chippings and overall a less favourable aesthetic outcome.

On that score the physical properties of veneering materials are constantly being improved and new veneering techniques are developed. Recently Beuer et al described a new veneering method using CAD/CAM-fabrication. (12) In an in-vitro setting the veneering ceramic was milled, sintered to zirconia copings (CAD-on-technique) and compared with anatomically identical zirconia-based crowns veneered by either over-pressed or conventionally layered veneering ceramic. The fracture load of the CAD/CAM-veneered zirconia copings showed to be superior to the conventionally layered reconstructions. (12) Therefore this new veneering method may be advantageous in terms of cost reduction and chipping rate. Whether the CAD/CAM-technique will lead to less chippings in all-ceramic reconstructions, remains to be investigated in a clinical setting.

## Conclusions

FDPs with zirconia frameworks and overpressed veneering ceramics show relatively good short-term survival rates. There are differences though in technical outcomes when compared to conventional layering as chippings occurred more often in the pressed group. Within this study no significant benefit could be shown for the overpressing of the veneering ceramic in all-ceramic reconstructions.

Further long-term studies are needed to show how the technical complications evolve over time. Furthermore, more clinical studies are needed to investigate whether the development of new veneering ceramics for zirconia frameworks will be a viable alternative or if there will be a tendency towards full-anatomical zirconia-reconstructions.

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## Material & Methods

The technical outcome was assessed using modified United States Public

Health Services (USPHS) criteria. (Bayne and Schmalz 2005)

(Table 1)

	<b>Alpha (A)</b>	<b>Bravo (B)</b>	<b>Charlie (C)</b>	<b>Delta (D)</b>
<b>Framework fracture</b>	No fracture of framework			
<b>Veneering fracture</b>	No fracture	Chipping, but polishing possible	Chipping down to framework	New reconstruction is mandatory
<b>Occlusal wear</b>	No wear facets on restoration and opposing teeth	Small wear facets (diameter <2mm) on restoration and/or opposing teeth	Wear facets (diameter >2mm) on restoration and/or opposing teeth	New reconstruction is needed
<b>Marginal adaptation</b>	Probe does not catch	Probe catches slightly, but no gap detectable	Gap with dentin or cement exposure	New reconstruction is needed
<b>Anatomical form</b>	Ideal anatomical shape; good proximal contact	Slightly over- or under-contoured; weak proximal contact	Highly over- or under-contoured; open proximal contact	New reconstruction is needed
<b>Radiographs</b>	No visible cementation gap on x-Ray	Minor gap visible		
<b>Patient satisfaction</b>	Very satisfied	Temporarily not satisfied (eg Postinsertion sensitivity)	Not satisfied Tolerable discomfort	Not satisfied Intolerable discomfort or dislike



## Results

Table 2a gives detailed information on the number of the FDPs and their respective location.

<b>Reconstructed tooth</b>	<b>Molar (n)</b>	<b>Premolar (n)</b>	<b>Total (n)</b>
<b>Test group (pressed)</b>	<b>14</b>	<b>6</b>	<b>20</b>
Maxilla	1	5	6
Mandible	13	1	14
<b>Control group (layered)</b>	<b>14</b>	<b>6</b>	<b>20</b>
Maxilla	6	4	10
Mandible	8	2	10

Table 2a

Tables 2b-e give detailed information on the reconstructions at the 3-year examination on allocation, gender distribution and wear time.

<b>Reconstructed tooth</b>	<b>Molar (n)</b>	<b>Premolar (n)</b>	<b>Total (n)</b>
<b>Test group (pressed)</b>	<b>13</b>	<b>5</b>	<b>18</b>
Maxilla	1	4	5

Mandible	12	1	13
<b>Control group (layered)</b>	<b>12</b>	<b>6</b>	<b>18</b>
Maxilla	5	4	9
Mandible	7	2	9

Table 2b

<b>Reconstructed tooth</b>	<b>Molar (n)</b>	<b>Premolar (n)</b>	<b>Total (n)</b>
Maxilla	6	8	14
Mandible	19	3	22

Table 2c

	<b>female (n)</b>	<b>male (n)</b>	<b>Total (n)</b>
Patients	25	11	36

Table 2d

	<b>age (mean)</b>	<b>observation period (mean)</b>
Control group	52.3y (46.9-57.6y)	36.8m (32.5-41.1m)
Test group	55.8y (50.6-60.9y)	34.9m (29.6-40.2m)

Table 2e

The technical outcome was assessed using modified United States Public Health Services (USPHS) criteria.

(Table 3)

	Alpha (A)	Bravo (B)		overall
<b>Marginal adaptation</b> <u>Overall</u>	30%	70%		
<b>Occlusal wear</b> <u>Test group</u> <u>Control group</u>  <u>Overall</u>	30% 65%  47.5%  (No wear facets on restoration and opposing teeth)	70% 35%  52.5%  (Small wear facets (diameter <2mm) on restoration and/or opposing teeth Small wear facets (diameter <2mm) on restoration and/or opposing teeth)		Breslow 0.478 Fischer 0.056% (not significant)
<b>Anatomical form</b> <u>Test group</u> <u>Control group</u>	90% 95%			92.5%
<b>Interproximal contact</b> <u>Test group</u> <u>Control group</u>	95% 90%			92.5%

<b>Radiographs</b>				
<u>Test group</u>	70.6%			78.4%
<u>Control group</u>	85%	(Minor gap visible)		
	(No visible cementation gap on x-Ray)			

<b>Patient satisfaction</b>				
<u>Test group</u>	75%	25%	Not satisfied Tolerable discomfort	Not satisfied Intolerable discomfort or dislike
<u>Control group</u>	100%	Temporarily not satisfied (eg Postinsertion sensitivity)		
	(Very satisfied)			

Detailed information on the chipping rate is given in Table 4.

	No chipping	Minor chipping (polishable)	Chipping to framework	Total No. Chipping
<b>Test group (pressed)</b>	10	3	5 (27.7%)	8

<b>Control group (layered)</b>	14	2	2 (11.1%)	4
<b>Total</b>	(77%)	(13.8%)	(19.4%)	36

Table 4

Biological outcomes Table 5.

	Plaque Index (PI)	Bleeding on Probing (BoP)	Pocket Probing Depth (PPD)
<b>Test group (pressed)</b>	-0.875	-0.069	0.050
<b>Control group (layered)</b>	-.1437	-0.050	-0.013
<b>p-value</b>	0.003	0.297	0.878

